THE BROWN OR YELLOW LOAM OF NORTH MISSISSIPPI, AND ITS RELATION TO THE NORTHERN DRIFT.[1]

OUTLINE.

I. General characteristics of the Brown or Yellow Loam.

II. Its stratigraphic relations and its distribution in north Mississippi.

A. Its relations to the Lafayette.

Unconformity between the Brown Loam and the Lafayette proper indicated by:

(1) The fact that wherever the Lafayette occurs in force, covered by the loam, the greater part of the present surface relief is due to the irregular contours of the Lafayette, rather than to varying thickness of the former, resulting from recent erosion: topographic relief of the Lafayette greater than that of the Brown Loam.

(2) (*a*) The feathering out of the Lafayette, and its alternate disappearance and reappearance eastward and northeast from Oxford, Miss., thus leaving erosion remnants intercalated between the Brown Loam and pre-Lafayette formations.

(*b*) The presence in the surface formation of northeast Mississippi, where, in many places, the Lafayette is now absent, of materials similar to those of the Lafayette where typically developed.

(3) The degree of oxidation produced in the Lafayette prior to the deposition of the Brown Loam.

(4) The occasional presence of thin patches of a seemingly distinct formation intercalated between the two, composed of materials similar to those of the Lafayette, but unconformable alike with the Lafayette below and with the Brown Loam above, thus indicating, probably, *two erosion intervals* of greater or less duration between the time of the deposition of the Lafayette and that of the Brown Loam.

(5) The character of fossil plants found in bowlders of clay in this intermediate formation, near Oxford, Miss., and derived presumably from the Lafayette.

Summary: The preglacial age of the Lafayette.

B. Its relation to the Loess (or Bluff formation of Hilgard).

III. Origin and age of the Loess Loam.

A. Lower limit of the formation in north Mississippi.

B. Upper limit in the same region.

C. Conditions under which the formation was deposited.

D. Subsequent alteration.

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[1] This paper is based upon a series of personal observations extending continuously from Riverton, Alabama, to Memphis, Tennessee, in a crescentic curve passing

I. GENERAL CHARACTERISTICS OF THE BROWN OR YELLOW LOAM.

The predominant material of the formation in this section to which Hilgard has applied the name of brown loam, or yellow loam is as he states (*Agriculture and Geology of Mississippi*, p. 198), "that of a mellow clay or loam, without any definite structure or cleavage, variously tinged with iron; containing from 10 to 25 per cent., usually, of siliceous sand, the rest being clay mixed with finely divided silica, and forming, therefore, rather loose, mellow soils, and good brick clays.

The loam proper of this formation varies from the brownish-black color of our richest upland soils, where the coloration is due largely to the presence of organic matter through yellow and red, to the grayish-white "buckshot," or "crawfish," lands, which are ill suited to agricultural purposes.

In view of the immense value of these "buckshot" (which characterize the lands of that name by their presence in large number) to the geologist in enabling him to identify with reasonable certainty loams of this period occurring in this region, a brief description of them will not be out of place. They are not confined to the so-called "buckshot" or "crawfish" lands, but

through the counties of Tishomingo, Prentiss, Union, Lee, Pontotoc, Lafayette, Yalobusha, Panola, Tate, Marshall, and De Soto in Mississippi, and Shelby county, Tennessee.

In its preparation invaluable aid has been received from the writings of Hilgard, McGee, Chamberlin, and Salisbury. To my former instructors in field geology, Messrs. A. P. Brigham, H. B. Kümmel, and T. C. Chamberlin, credit is due for valuable training in field methods; to Professors Chamberlin and Salisbury I am also indebted not only for instruction in the theoretical aspects of the science, but for suggestions as well, given both in and out of the class room, bearing upon the subject under discussion; and to Professor Chamberlin I am under special obligations for a critical review of the first draft of this article.

Thanks are also due to Mr. Charles Strong, M.A., former Fellow in Chemistry, University of Mississippi, for a chemical analysis of "buckshot" from the yellow loam; to Dr. F. H. Knowlton, for the identification of fossil plants herein described, and to various others for kindnesses shown me.

But for the collection and collation of data on which this paper is based, and for the conclusions derived therefrom, I alone am responsible. The accompanying photographs were taken by Sanders and Sweeney, Oxford, Mississippi.

are liable to be found, in smaller numbers, wherever the Brown Loam occurs, and one will rarely travel far in the loam region without finding them. They seem to be entirely characteristic of the Brown Loam in this vicinity, not being found in any of the older formations on which it directly rests—that is, as far as my observation extends—and over most of the territory the loam is itself the surface formation. It is true that along streams frequently "second bottoms" are to be found (sometimes as "buckshot" lands), and the more recent alluvial deposits, the latter, however, never containing concretions: but the former are undoubtedly, in many cases, merely terraces of degradation cut in the Brown Loam, when, because of increased velocity due to increase of slope or to decrease of burden, or to both, the streams began to erode the bottoms of their channels more rapidly than their sides, and so ceased to overflow only within the past twenty-five or thirty years.

But it is not always an easy matter in the field to separate the loam from more recent formations. This subject will be more fully treated under the head "Upper Limit in the same Region."

These "buckshot" are usually more or less rounded, yellowish-brown on the oxidized surface, black in the interior, possessing no definite structure, and ranging in size from that of a small shot to that of a small marble. Not infrequently, however, they are much larger, when they usually tend to become more flattened and angular, and are frequently found cemented by iron oxide into a rather friable conglomerate.

These ferruginous concretions have undoubtedly been formed by segregation from the mass of the loam, as have somewhat similar ferruginous concretions and the calcareous nodules from the loess, and especially the friable conglomerate already mentioned, has evidently been cemented *in situ*. (Compare paragraph 338, p. 199, *Agriculture and Geology of Mississippi*.) Typical specimens of the "buckshot" from the loam of Tate county, ground up together and analyzed at my request by Mr. Charles Strong afforded:

	Per cent.
Silica (SiO_2),	78.55
Ferric oxide (Fe_2O_3),	14.88
Water,	1.51
Sulphuric acid (H_2SO_4),	1.03
Lime (CaO),	1.944
Alumina (Al_2O_3),	2.06
Total,	99.974

Perhaps the most notable characteristic of the brown loam is its general disintegrated, "rotten" appearance, with the entire absence of anything simulating stratification in the loam proper, notwithstanding the fact that the particles composing it are usually fine and such as ought, it seems, to have been neatly stratified if deposited under ordinary conditions, and not subjected to subsequent atmospheric and aqueous action. This subject will be more fully discussed under the general head, "Origin and Age of the Loess-Loam."

II. STRATIGRAPHIC RELATIONS AND DISTRIBUTION OF THE BROWN LOAM OF NORTH MISSISSIPPI.

According to Hilgard (*Agriculture and Geology of Mississippi*, pp. 197–198), "the yellow, brown, or reddish loams which have been repeatedly mentioned as forming the surface, and therefore essentially, the soils of the greater portions of the State of Mississippi constitute to all appearance an independent aqueous deposit, posterior to the Orange Sand (Lafayette) and the Bluff formation, and anterior to the alluvial formations of the present epoch. The great thickness which this loam stratum attains in some regions, its distinct definition as well as its comparative independence as to its character of the formations immediately underlying, preclude its being claimed as a mere surface disintegration of the older formations. The nature of its materials and the entire absence of stratification lines distinguish it sufficiently from the Orange Sand where it immediately overlies the latter; while the absence of any large amount of lime, except where it is in immediate contact with strongly calcareous formations, the

presence of a considerable amount of hydrated peroxide of iron as well as the want of proper fossils as distinctly separate it from the Bluff formation of the Mississippi River. . . . .

"From the appearance of the loam stratum, even on high ridges and elevated uplands, it is obvious that its deposition took place, in part at least, anterior to the great denudations which have produced the present surface configuration; nevertheless, its increasing thickness as we approach the immediate valley of the Mississippi shows, as in the case of the Bluff formation, that this great channel was already in existence.

"On the Tombigbee, and on the lower Tallahatchie, Yalobusha, and Big Black, a similar increase in the thickness of the loam stratum may be observed. But on the smaller water courses this is the case only to a very limited extent, showing that, although at the time of the deposition of the loam the channels were already more or less impressed upon the surface and high ridges existed which remained above the level of the water which deposited the loam, the minor denudations which have caused the present undulating surface had as yet exerted but little influence. The lines of contact between the Orange Sand and Loam, where the latter is evidently *in situ*, are generally much less undulating than are those between the Orange Sand and the older formations."

A. *Relation of the Brown Loam to the Lafayette.*—From the foregoing account, it would appear that the Brown or Yellow Loam proper is a formation *sui generis*, deposited on a previously eroded land surface in such wise as not to turn aside the larger preëxistent streams, and distinguished from the Lafayette only by "the nature of its materials, and the entire absence of stratification lines where it immediately overlies the latter." These criteria for the discrimination of the Brown Loam and the Lafayette will, of course, fail of application (1) where there is no great difference in the nature of the materials of the two formations, as is frequently the case, especially near their line of contact, and (2) where the upper part of the Lafayette, as well as the Brown Loam, is unstratified.

Wherever the loam attains a thickness of 10 or 12 feet—and it is rarely thinner than this for any considerable distance—it is usually not difficult to identify it, especially its upper portion, but, as Hilgard has long ago pointed out, this formation is frequently so modified by underlying terranes as to render its delimitation in those places a matter of great difficulty, if not impossible. For instance, locally the characteristic loam may be replaced by sand variously colored; and when all traces of stratification, if they ever existed, have become obliterated through the action of percolating chalybeate waters, which both color and cement the sand grains, and when this red, sandy phase of the "Brown Loam" or "Yellow Loam" rests directly upon similar sands of the Lafayette—whence the former have generally been derived—it frequently becomes a matter of impossibility to draw any certain line between the two. This is often the case in the "red lands" of the Pontotoc Ridge and its northward continuation, the "Buncombe Hills." However, judging from an exposure near the depot in the town of Pontotoc, and from numerous other sections on the ridge, both the brown loam and the Lafayette seem to be represented in the Pontotoc Ridge; but as we shall presently see, the Lafayette is frequently absent in northeast Mississippi, the Brown Loam resting directly upon still older formations.

A section in the cut on the Illinois Central Railroad just south of the depot at Oxford shows typical loam at the top, grading into rotten or friable clay, which, becoming more sandy below, passes insensibly into a semi-indurate, massive red sandstone. The base of the section here shows nicely stratified sands and clays, presumably of Lafayette age, though possibly later, but no definite line can be drawn between the two formations at this exact point.

While we cannot always with certainty determine, in the field, the limits of the two formations, and while there are to be found places of seeming local conformity, which we should naturally expect, still the two can generally be separated without difficulty, because, when typically developed, the two forma-

tions possess little in common. And from such good exposures I have obtained strong evidence of great and widespread unconformity between the Brown Loam and all older formations. A great erosion interval is indicated by the following facts:

1. A considerable interval of erosion between the Lafayette and the Brown Loam periods is indicated by the fact that wherever the two occur in force the greater part of the present surface relief is due to the irregular contours of the Lafayette rather than to varying thickness of the post-Lafayette resulting from recent erosion. In other words, the topographic relief is greater in the Lafayette than in the post-Lafayette. This is indicated by the greater thickness of the post-Lafayette in existing valleys than on hilltops, even where there has been no recent deposition in the former of loam washed in from the hills. Many Lafayette hilltops, frequently capped with ferruginous sandstone bowlders, seem to have been above water continuously since Lafayette times. It seems that the land in this region has not been under water long enough since the period of Lafayette erosion to allow the complete filling in of the channels cut in the Lafayette; and this is partly due to the fact that deposition was taking place simultaneously, though not to so great an extent, over the greater part of the hills and ridges into which the Lafayette had been cut. And so the most of our present streams, especially the larger ones, are of the superimposed type—superimposed by sedimentation.

The greater deposit of sediment in the valleys is probably due to the fact that the valleys were submerged for a longer time, but partly also to the greater effect of their deeper waters in the checking of currents and consequent precipitation of sediments.

2. Another line of evidence of unconformity between the Lafayette and the Brown Loam, closely related to the one just given, lies in the fact that the Lafayette frequently feathers out, leaving the Brown Loam to rest directly upon the formations older than the Lafayette. Sometimes the evidence of the former extension of the Lafayette over the area in question is not con-

clusive, as where the Brown Loam rests directly upon the pre-Lafayette formations, and there is no trace of the Lafayette left in the vicinity, it is impracticable under such circumstances to say whether the Lafayette once covered the given locality and has been entirely removed by erosion, or whether it was never present. Such a state of things is exhibited in many places in the country near New Albany, Miss., and elsewhere. The Brown Loam mantles the hills and dales of this region, resting in many places directly upon the Cretaceous, sometimes upon the Lafayette, as it does elsewhere (as we shall presently see) upon the Lignitic Tertiary, and as it does regularly upon the Lafayette further westward. It cannot be a surface disintegration of the Cretaceous at this place; but it is seen to be directly continuous with the loam stratum elsewhere observed, and was without doubt formed at the same time and in the same way. (As to the geological relations of the surface soil, Brown Loam, in this region, see also *Ag. & Geol. of Miss.*, paragraphs 335, 336, and 337, pp. 198–199.)

But sometimes the Brown Loam rests upon older formations once covered by the Lafayette, which has subsequently been removed by erosion. There are two lines of evidence: (*a*) Near Oxford, Miss., where the Lafayette is typically developed, it attains a maximum thickness of something like 200 feet. But towards the east it soon thins out, exposures of the Lignitic being quite common within eight or ten miles of Oxford.

As the region of Flatwoods is approached, the Lafayette becomes discontinuous, and patches of it only are to be found intercalated between the Brown Loam and the Northern Lignitic. The Lafayette seems to give out altogether several miles before the Flatwoods are reached. At the exact western limit of the Flatwoods, some ten miles west of Pontotoc, on the Pontotoc and Lafayette Springs road, several feet of typical brown loam are seen to rest directly upon the blue clays of the Lignitic. Over the Flatwoods region, here six or seven miles wide, both the Brown Loam and the Lafayette are usually absent, the latter always, the former occurring in limited patches towards its east-

ern border. Both formations seem to be found again in the Pontotoc Ridge and Buncombe Hills, as already noted; but the Lafayette soon gives out and seems not to appear again, at least not strongly and typically developed. For example, over the greater part of Union, Prentiss, and Tishomingo counties, the Brown Loam rests upon formations older than the Lafayette. Frequently the Brown Loam has been removed by erosion, and the "Rotten" Limestone, Selma, or Tombigbee Chalk comes to the surface. Exposures of this latter formation are quite common in the prairie region, as is well shown around Booneville, Baldwyn, Marietta Springs, etc.

On a hilltop about fourteen miles from Booneville and sixteen miles from Iuka, on the old Booneville and Iuka road, several feet of Yellow Loam repose directly upon stratified, blue, pyritiferous clay of the Eutaw (?) group.

At Bay Springs, in southwest Tishomingo county, the Brown Loam rests either directly upon Sub-Carboniferous sandstone or there is a thin intervening stratum of pyritiferous Eutaw (?) clay — the source of the chalybeate waters of the springs. (*b*) While there is plenty of orange-colored sand in east Prentiss and in west Tishomingo counties, nowhere in this region did we find materials of undoubted Lafayette age *in situ*, though it seems likely that the Lafayette once covered this area, and that small patches of erosion remnants may still exist, because materials similar to those found in the Lafayette further west are here found to a greater or less extent scattered irregularly through the Brown Loam. The quartzose pebbles of Tishomingo county, for example, described by Hilgard (*Ag. & Geol. of Miss.*, 1860), and referred to the Lafayette epoch, seem to occupy an entirely different stratigraphic position from the majority of those in the western region, *i. e.*, from Memphis, Tenn., to Grenada, Miss., and southward, which are evidently of Lafayette age. In the former region these pebbles are found intermingled with the Brown Loam, as shown in many places near Iuka and elsewhere, while in the latter region they are invariably below the Brown Loam, sometimes in apparent local con-

formity with its base, elsewhere well within the Lafayette The gravels of this western belt were all evidently first transported to this region and deposited during the Lafayette epoch, and towards its close, though in many places they have been subsequently moved locally and redeposited at the base of the brown loam. On the principle of homogeny, the gravels of the eastern belt are thought to have been brought down originally at the same time with, and in the same manner, as those of the western region; but owing to the complete, or almost complete, removal by erosion of the Lafayette in the eastern region, these gravels have been shifted from their original positions and redeposited within the Brown Loam, and by the same waters (for I hold the Brown Loam to be essentially an aqueous deposit) which deposited the finer materials of the brown loam. These waters need not have been swift in order to transport pebbles, for these were probably only locally shifted and let down from higher to lower levels. On the other hand, the fineness of the materials of the bulk of this formation gives evidence that the formation, as a whole, was deposited by sluggish currents overloaded with fine sediment.

And so an application of the principles of homogeny, as defined by McGee (*12th Ann. Rep. U. S. Geol. Surv.*, p. 381 *et seq.*) to the Brown Loam of the whole of north Mississippi, together with the fact that undoubted erosion remnants of the Lafayette are to be found as far east as the Pontotoc Ridge, would seem to demand the former extension of the Lafayette over the whole of the area in question. A comparison of the hypsographic distribution of existing patches of the Lafayette with the hydrography of the region strengthens this conclusion, since remnants of the Lafayette are to be found on the highest hills, while on lower lands near by, the Lafayette may be entirely absent. As to the original thickness of the Lafayette, we have no way of determining this; but the evidence, direct and indirect, just presented, indicates a considerable erosion interval between the Lafayette and the Brown Loam during which a large part of the former had been removed prior to the deposition of the latter.

3. The degree of oxidation and attendant phenomena produced in the Lafayette prior to the deposition of the Yellow Loam, by atmospheric and aqueous agencies, likewise tell the story of a considerable interval of chemical as well as mechanical erosion between the periods represented by these two formamations. (See *Am. Jour. Sci.*, Vol. XLI, p. 370.)

4. The facts already presented show conclusively that a long period of erosion intervened between the time of deposition of the Lafayette and that of the Yellow Loam. Over most of the area embraced within the scope of this paper the Lafayette seems to be essentially a continuous deposit, with the Yellow Loam resting directly and unconformably upon it, although its irregular stratification and the alternating layers of coarser and finer material indicate varying local conditions such as would result if the formation were deposited in the manner supposed by Hilgard.

McGee finds evidence in some localities of a twofold and even of a threefold division of the Lafayette, the divisions being separated by "pseudo-unconformities," which, according to him, represent only local shifting of currents, and consequent change in deposition, and do not mark the limits of distinct episodes. (*12th Ann. Rep. U. S. Geol. Surv.*, pp. 453–456, and elsewhere.)

But sections observed by the writer have caused him to doubt the unity of the Lafayette, as now defined in its type locality, and to raise the question whether the uppermost member of the Lafayette may not represent a distinct formation.

Occasionally there is found a stratum of clay and sand, or of clay alone, intercalated between the main bulk of the Lafayette and the Yellow Loam, and sharply separated from both by irregular or billowy erosion lines. This deposit is usually only a few feet in thickness, and consists, (*a*) of compactly bedded pipe clay, (*b*) of interlaminated clay and sand (the different layers sometimes quite thin, sometimes several inches thick), or (*c*) of a heterogeneous, unsorted mixture of sand and clay bowlders of various shapes and dimensions, resembling very much in physical characteristics, the unsorted till of the North.

An excellent illustration of the first is found in an exposure of some thirty or thirty-five feet, four and one-half miles south of Chulahoma, Marshall county, Mississippi. Here we find several feet of compactly bedded pipe clay, with a billowy upper surface, covered by eight or ten feet of Yellow Loam—from which it is quite sharply separated—and resting upon a decidedly eroded surface of cross laminated Lafayette sand. The three formations are distinctly traceable for perhaps a hundred yards, when the surface of the Lafayette descends so far as to be no longer exposed. Stratigraphically and lithologically the three formations are here very distinct, and show no evidence whatever of grading into one another. The erosion line between the clay and the sand is as sharply defined as that between the clay and the Yellow Loam. This clay, moreover, gives evidence, in its irregular streakings of ferric oxide, of having once been highly fossiliferous, and this evidence is strengthened by the fact that it still contains a few leaves in a fine state of preservation. These fossils were evidently formed *in situ* and not plucked from older formations and redeposited. Not enough were found to be of any practical value in determining the geological age of the clay stratum in which they occur, and those found have not been identified. Of the specimens in my collection at least two distinct species are represented, the one having a very small netted veined, linear-oblong leaf, resembling a willow leaf, or the leaf of a water oak, the other also netted veined, oblong-ovate, and entire, but much larger than the first, being about an inch broad by two and a half inches in length. If the formation in question belongs to the Lafayette, then the Lafayette here contains fossils of its own in its upper part; but it appears to belong to a distinct epoch or episode, and the presence of fossils in clay would seem to indicate conditions of deposition different from those which appear to have obtained when the Lafayette sand, directly underneath, was being deposited.

The accompanying photographs represent a continuous section one-third of a mile north of the depot at Oxford, Mississippi. A cut in the Illinois Central Railroad at this place, giv-

ing an exposure of thirty to thirty-five feet, shows a section very similar to the one just described, except that the middle member here consists of eight to twelve feet of clay bowlders, large and small, rounded and angular, mixed indiscriminately with sand. This section shows:

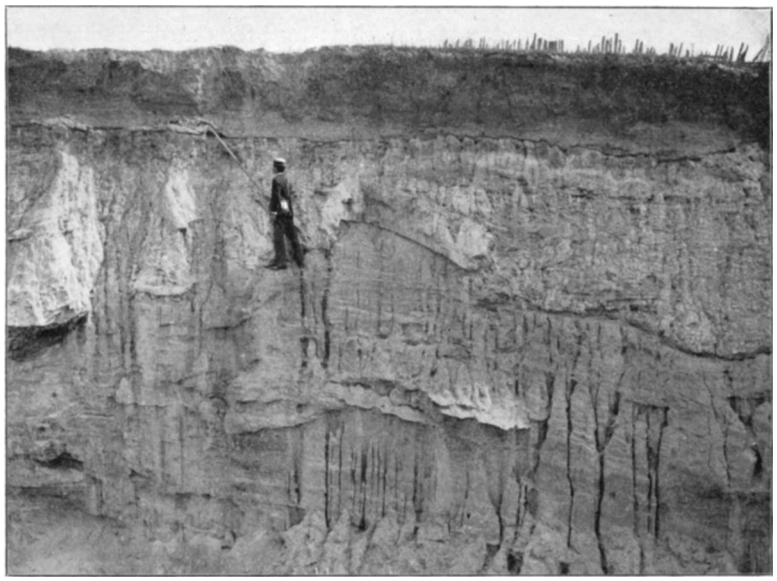

FIG. 1.—Section near the depot at Oxford, Mississippi, showing two members of the Columbia Formation and their relation to the Lafayette. (*a*) Yellow Loam; (*b*) fossiliferous clay bowlders and sand; (*c*) cross-laminated Lafayette Sand.

(*a*) At top, 0–8 feet of Yellow Loam.

(*b*) 8–12 feet of clay bowlders and sand.

(*c*) At base, 0–12 feet of cross stratified Lafayette sand.

Here the three formations are very distinct lithologically, and there is no evidence of the gradation of one into another either in a lateral or in a vertical direction.

The top stratum (*a*) is a typical loam, while (*b*) consists of sand mixed with clay bowlders, rounded and angular, varying in size from mere pellets up to slabs one to two feet thick, four to six feet long, and of unknown width, but presumably of not

more than a few feet. The lowest stratum (*c*) has been sufficiently described above.

This bowlder stratum (*b*) consists of rock materials similar to those of the directly underlying or adjacent Lafayette; so from a lithological standpoint two views of the origin of this stratum are possible. Either it and (*c*) have been derived from the same pre-Lafayette formation, or formations, and the apparent unconformity between them is to be regarded as a "pseudo-unconformity," as explained by McGee, or the two are distinct formations, and the upper one has been derived from the lower.

The latter I regard as the more probable for the following reasons:

1. The extent to which the underlying sands have been eroded, and the very abrupt change from cross laminated sands (seemingly a local delta deposit) underneath, to a bowlder stratum of the character described—these seem to indicate extraordinary conditions of deposition for the bowlder stratum, and an amount of erosion of the underlying formation, which could not be accounted for by a mere local shifting of currents, with no appreciable changes of level nor consequent interval of erosion.

Smaller clay pellets, it is true, occur quite frequently elsewhere, in the body of the Lafayette, but never so large, as far as I am aware, as those just described.

2. The size of many of these bowlders, and their frequent angularity (which may be due in part, however, to subsequent atmospheric action), as well as their composition and physical texture, render it highly improbable that they have been transported by running water for any considerable distance.

The Lafayette proper is about 150 to 180 feet thick in this vicinity, as shown by recent well borings; and the Lignitic, the immediately underlying deposit, comes to the surface only at a distance of several miles to the eastward. A well recently bored upon the university campus, after passing through a few feet of surface loam penetrated the Lafayette formation, and

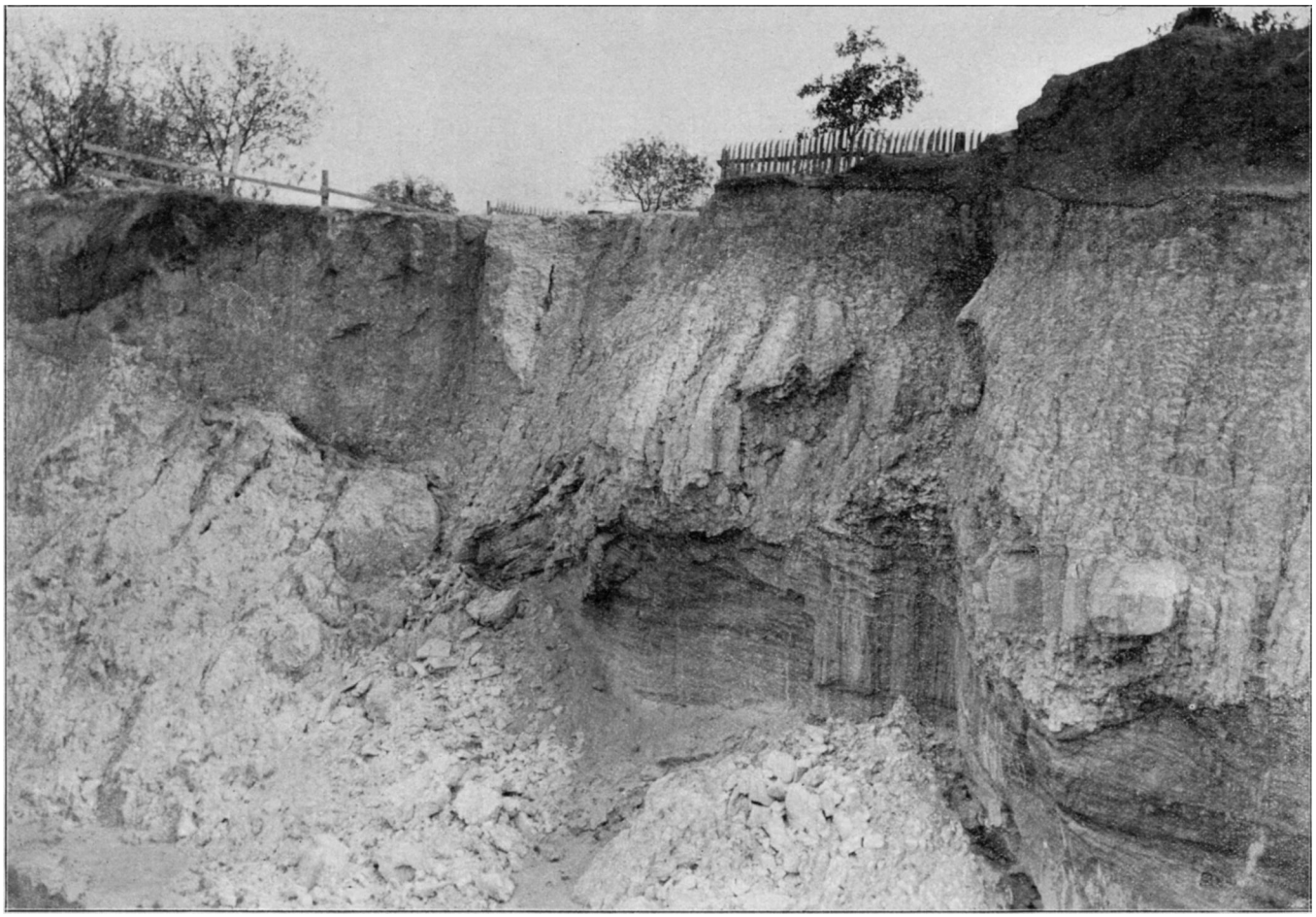

FIG. 2.—Northward continuation of Fig. 1. (*a*) here removed from center of photograph by erosion. Talus at base composed largely of

reached the Lignitic beds at a depth of about 180 feet. Wells in Oxford struck the same beds at depths of 155 to 160 feet.

The pipe clay of which these bowlders are composed is also of an unctuous, kaolinic nature, such as would not seem able to suffer prolonged transportation by running water without disintegration.

3. The clays of this bowlder stratum are altogether unlike those of the Lignitic beds near here, which are generally blue, or black, pyritiferous, and friable when dry. But the clays, also, of the Lafayette proper, which must have come from a distance, show a like dissimilarity to the Lignitic clays, having become altered probably in color and relieved largely of carbonaceous matter and of iron pyrites (if they came from the Lignitic) during transportation or subsequent to their redeposition. So the argument based on the dissimilarity of the clay bowlders to clays of pre-Lafayette age in this vicinity is of no value considered apart from the conditions under which they must have been deposited, and the short distance to which they could have been transported by running water.

4. These bowlders are frequently highly fossiliferous, containing plant specimens preserved in ferric oxide, and prolonged water transportation, if possible, would probably have defossilized them by the removal of the iron oxide in solution. The fact that no well-defined fossils peculiar to itself have yet been found in the Lafayette might be adduced as evidence that these fossiliferous bowlders must have come from some other source (and the character of the fossils as described by Dr. Knowlton would seem possibly to indicate their derivation from an earlier formation); but this does not necessarily follow, since plants must have existed during the Lafayette, and if none have been found in it the explanation is probably to be found in the fact that its materials, as a rule, are not well adapted to the preservation of organic remains. Its clays, moreover, as already pointed out, are very similar to those of the stratum under discussion, and the latter are very rarely fossiliferous. It is only occasionally that we find fossils in compact, close-textured, impermeable and

highly colored clays. Where there has been freer circulation of water, and where roots of recent plants have penetrated them, these clays have become more friable and partially decolorized, the change from their former condition being indicated, as already noted, by the peculiar distribution of the remaining ferric oxide, which frequently retains the shape of stems and leaves but not their texture. And in many instances such markings are traceable by the lighter color and by the more disintegrated condition of the clay where fossils seem to have existed, the ferric oxide having been, it seems, more completely removed, subsequently, than from the surrounding clay. Much care, however, is needed in the interpretation of many of these tracings, part of which are due to the action of roots of recent plants, part to the collection of ferric oxide on slickenside surfaces resulting from the jointing of the clay and the scratching of joint surfaces by their movement over sand grains. Such markings frequently give a fluted appearance resembling very much the impressions of parallel veined leaves.

The foregoing considerations, it seems to me, render it highly improbable that the coarser and clayey materials of this peculiar bowlder conglomerate could have been transported for the distance of several miles by running water.

The peculiar admixture of sand with clay bowlders, large and small, rounded and angular, with no trace of sorting, suggests to the writer the possibility of this deposit having been formed after a partial reëlevation succeeding the Lafayette subsidence, by the sapping of the banks of a small post-Lafayette lake or stream.

The inability to discover similar plant remains in the adjacent Lafayette might be explained by the removal of the original beds by plantation.

It is barely possible that this particular deposit may have been made by floating ice during the first interglacial epoch (or more probably during the first interglacial episode of the first glacial epoch), and I shall present, later, evidence of iceberg action at this time, in this vicinity — but the elevation of

this deposit above the larger water courses, such as the Tallahatchie and Yocona rivers, between which it lies and down whose swifter waters most of the icebergs probably traveled, renders it hardly probable that the deposit was formed in this way.

According to Professor Chamberlin the Natchez formation occupies similar relations to the Lafayette and to the Loess of the northern Mississippi, though it contains crystalline pebbles in addition to materials derived from the Lafayette; and he suggests that both may have been formed at the same time, the two representing a distinct episode, or epoch, between the Lafayette and yellow loam.

On this hypothesis there was a period of upheaval succeeding the Lafayette deposition, during which all formations then existing were greatly eroded. This was followed by subsidence in the region of the lower Mississippi, accompanied by the deposition of the Natchez formation and of the stratum between the Lafayette proper and the Yellow Loam in this vicinity. Then followed an interval of upheaval and erosion, marked by the irregular contours of the upper surface of the bowlder stratum of the Oxford section and by the presence of an old soil at the summit of the Natchez formation. It is not to be understood, however, that the supposed Natchez subsidence was great enough to submerge the areas in question below sea level, for the deposits have not the characteristics and distribution which would probably have resulted from the action of ocean waves.

The deposits were probably formed when the land surface was at a comparative base level, and are of fluvial and lacustrine origin, and not marine, nor even estuarine. The amount of geological time represented by this hypothetical oscillation (during which the Natchez formation and its supposed congener in this vicinity were deposited and subsequently eroded prior to the deposition of the Loess and the Brown Loam) is probably very short, though it serves to emphasize the time interval between the Lafayette and the Brown Loam.

5. Other evidence bearing on the age of the Lafayette, and

therefore upon that of the Yellow Loam, is that furnished by the character of fossil plants found in the bowlder bed at Oxford previously described. The value of this evidence, however, is diminished by the fact that it is not absolutely certain that they came from the Lafayette formation. These fossils are mainly leaves and small stems, and occasionally an acorn (?), of what "seems to be a new and very fine species of Quercus" (Knowlton); and sometimes there is found a specimen of a palm, that "is with little doubt Flabellaria Florissanti, Lx, found originally in the Eocene of Colorado" (Knowlton). The preserving agent is apparently red hematite which shows up the smallest veinlets of the leaves. Indistinct traces of grass-like plants are also to be found. In answer to inquiries as to the probable age of these fossils, as referred to the accepted geological time scale, and the probable climatic conditions then prevailing, as indicated by the nature of the plants, Dr. Knowlton has this to say: "The data upon which to base an opinion of age is, as you see, quite too scant for a positive assertion. I should say, however, that it indicated rather an Eo-Lignitic than later age. Could it be possible that the clay in which the plants occur was a pocket or lens which had been torn from the Eo-Lignitic and redeposited in the Lafayette? However, I incline to the opinion that they are Eocene rather than later, but more material will be needed to confirm or disprove this . . . . the above mentioned plants do not indicate any marked change from the climate of the present day . . . . I imagine that when the fossil flora is thoroughly studied we shall find that species or forms have persisted for long periods of time with comparatively little change."

This paper deals with the study of the Lafayette formation only to the extent necessary for fixing the lower limit of the Yellow Loam. And the foregoing evidence of unconformity between the two is adduced in corroboration of the evidence presented by Chamberlin and Salisbury (*Am. Jour. Sci.* Vol. XLI, p. 359 *et seq.*) in favor of the preglacial age of the Lafayette. The proof of the glacial age of the Loess of the Missis-

sippi valley, presented by them in the article just referred to, appears conclusive.

I have shown that the Yellow Loam occupies the same position with reference to the Lafayette in the interior, that the Loess does along the Mississippi valley. By the foregoing considerations, and by a review of the relation of the Yellow Loam to this loess in this vicinity, I hope to strengthen the evidence already presented by McGee that the Yellow Loam and the Loess are not only homotoxial but that they are also genetically related.

B. *The relation of the Brown or Yellow Loam to the Loess (or Bluff formation of Hilgard).*— These two deposits were discriminated by Hilgard, who considered them as separate formations, the Brown Loam being the younger (*Ag. & Geol. of Miss.* 1860).

Later, McGee and others have noted the somewhat complex relations of the two along the bluffs of the southern Mississippi, especially around Vicksburg and Natchez (*12th Ann. Rept. U. S. Geol. Surv.*, p. 392 *et seq.*).

The present paper has nothing to do, except in a very general way, with this area, concerning which McGee says: "The loess of the lower Mississippi region may be characterized as a peculiar condition of the Brown Loam, or as an imperfectly demarked phase of the great formation into which both deposits fall." Having reached the same conclusion from a study of the area embraced within the scope of this paper I shall now proceed to state the grounds on which this opinion is based:

1. The Drift of the North is the surface formation, to which the loess of the river valleys bears an ascertained and definite relation, as already noted. During the Glacial period there were extensive continental oscillations during which, according to some authorities, the whole southern part of our continent was submerged: so, on *a priori* grounds, we should find as the "southern equivalent of the northern Drift" a mass of water-deposited sediment more commensurate in quantity with the Drift than is the Loess alone. Evidence of such submergence will be brought out in the further discussion of this subject.

2. Having traced the surface formations from Bear Creek, on the Alabama-Mississippi-Tennessee lines, to the Mississippi River at Memphis, and to the "bluffs," 40–50 miles below, I found the loess and the loam to be absolutely continuous, the former usually being absent, or not characteristically developed, except within a few miles at most of the existing "bluffs" and frequently in the "bluffs" themselves replaced entirely, locally, by loam, with characteristic ferruginous "buckshot," to the very base.

The following characteristic sections will serve for illustrations:

A. *Sections at Memphis, Tenn.*—(*a*) Bluff just north of Custom House; at base, typical bluff-colored loess, non-effervescent throughout its mass, but containing characteristic concretions, calcareous and ferruginous, — the latter tubular or cylindrical rather than rounded — and obscure fossils. This passes laterally into yellow or brown loam, and also becomes loamy at the top — as the loess quite frequently does. Evidently the loam here is only modified loess, or the latter is only a peculiar phase of the loam. This is the most characteristic exposure of the loess observed at Memphis. Going down the river both fossils and concretions (of the loess proper) become less frequent. (*b*) Section about one-half mile north of the river bridge; 60–70 feet (estimated) of typical brown loam with its characteristic "buckshot" to the very water's edge, where it rests unconformably on the Lafayette — the loess being entirely absent. Exposures near here show a loess-like loam devoid of fossils and concretions. (*c*) Section about one-third mile north of river bridge. (1) At top 60–70 feet of loam. (2) White and reddish sand, cross laminated, and containing occasional pebbles, sometimes stratified, 10 feet. (3) Stratified Lafayette gravel, 2–3 feet exposed. The lowest 5 or 6 feet of (1) are pronouncedly sandy, the upper part of (2) humus stained, indicating an old soil. (*d*) Section about 30 yards south of the last. Here we have about 60 feet of yellow loam, with "buckshot" at its very base, resting directly upon stratified

Lafayette gravel, No. (2) of the preceding section being absent.

B. *The relations of the Loess and the Brown Loam along the "bluffs" of southwest Tate and northwest Panola counties.*— In this region the bluff is much higher, though far less precipitous than at Memphis, where it is being continuously washed at its base. The estimated height of the rampart at Askew's Bluff, northwest Panola, is 200 feet. But thence it diminishes in altitude both northward and southward. Concretions and fossils are generally to be found in abundance within a few hundred yards eastward from the present base of the rampart in this region, but no clear cut section showed in any one place the characteristics and the relations of the Loess from the top down to the Lafayette. However, a continuous, descending section from the summit of Askew's Bluff passes over several feet of gravels, similar to those at Memphis and southward, about two-thirds of the way down. Further down, the blue clays of the Lignitic are struck and something like 40 or 50 feet are exposed; and one-quarter mile north, in a ravine, there is found a seam of cheesy lignite one or two feet thick. Traced eastward from this point the loess passes insensibly into the surface loam. The main body of the Loess here, as elsewhere, is as a rule, less disintegrated than the Yellow Loam; but the formation is apt to be more loam-like at the top, where most exposed to atmospheric action.

Traced northward the Loess seems to maintain its typical character as far as studied, *i. e.*, to the road running west from Senatobia. Proceeding eastward along this road from the bluff, here quite low, the shells soon disappear from the Loess, but limestone concretions were found as far as four or five miles from the foot of the bluff, at a point one mile east of Strayhorn. Between these two places the Loess frequently alternates with loam, and at one place, about one and one-half miles west of Strayhorn, limestone concretions and ferruginous "buckshot" were found associated together in a sort of loess-loam, which became more loamy at the top. Here, as frequently, the limestone concretions assume dendritic forms, caused evidently by

percolating calcareous waters in ramifying crevices. Specimens were taken from such crevices.

No microscopic examination of the loam was made for comparison of its mineralogical constituents with those of the loess; but owing to a greater degree of subsequent alteration in the former it seems doubtful whether such tests when made would prove entirely satisfactory. The chemical composition of the two, in their typical development, seems to differ rather in degree than in kind, from the same cause, and the two pass into each other by insensible gradations.

From the foregoing it would appear that, if my observations be accurate, the Brown Loam and the Loess of this region are not only homotaxial but synchronous as well.

III. ORIGIN AND AGE OF THE LOESS LOAM.

The Loess of the north has been distinguished as belonging to two separate epochs, and a similar twofold division of the same in the south is mentioned as a probability by Chamberlin and Salisbury, in an article entitled "On the Relationship of Pleistocene to the pre-Pleistocene formations of the Mississippi Basin, south of the limit of glaciation" (*Am. Jour. Sci.*, Vol. XLI). The Yellow Loam is here considered as the interfluvial equivalent of the Loess, but the writer has seen nothing to suggest, or which would justify, the division of the former into two or more parts, separated by a time interval of greater or less duration. On the other hand, sedimentation generally seems to have been continuous from the beginning to the close of the period —the first deposits, frequently composed mainly of local and coarser materials, being directly followed by the finer deposits which constitute the main bulk of the formation. It does not follow that the Yellow Loam formation may not be of a bipartite nature elsewhere; and if it should prove universally indivisible this need not antagonize the idea of a twofold division of the Loess, because owing to elevation, or other causes, there may have been no interstream deposit here contemporaneous with one epoch or the other of the Loess, the deposition of which seems

to have been confined to the vicinity of the river courses at that time.

I may call attention, however, to the fact that in section *c* of the bluff at Memphis, as previously described, a humus stained horizon, indicating an old soil, was found at the upper surface of number 2, but this seemed to me to be the upper surface of the Lafayette, and not a part of the Loess-Loam at that place.

Because of the evident twofold division of the Loess in the north we should naturally expect the same for the Loess in the south, and perhaps for its interfluvial equivalent, the yellow or brownish surface loams. But this does not necessarily follow, for reasons stated above, and the results of my observations, considered without regard to exposures which I have never seen in other localities, will not justify me in an attempt to subdivide the Loess-Loam formation of this region. The formation is, therefore, considered in its entirety and the question of its delimitation discussed more fully in the following paragraphs.

A. *Lower limit of the Loess-Loam.*—This subject has already been discussed more or less fully in the description of the stratigraphic relations of the Brown Loam. The first Glacial epoch is divided by Chamberlin and Salisbury (*Am. Jour. Sci.*, Vol. XLI, pp. 362–363) into two episodes, and the inferior member of the Loess is referred to the close of the second Glacial episode of the first Glacial epoch. From the foregoing evidence it will be seen that the Brown Loam cannot be earlier, and that it is the interfluvial equivalent of at least one, perhaps of both, divisions of the Loess. And neither seems to be the full representative, in the South, of the northern Drift. The Natchez formation was probably deposited during the first Glacial episode of the first Glacial epoch, and towards its close, and I have given reasons above for believing that the same episode is represented in north Mississippi by scattered patches of subaërial deposits. These deposits, as already noted, are composed of local material, and while they may be contemporaneous with the earlier Drift, they are not genetically related to it, as the Natchez formation along the river is said to be.

The Brown Loam and its substratum in many places in this vicinity show a remarkable similarity to the Columbia formation of McGee as described at its type locality. Yet the facts recited above suggest that perhaps the Pleistocene history of the lower Mississippi may not be so simple as he has pictured it. But it is important to note, in this connection, that evidence of a distinct episode between the Lafayette and the Brown Loam is confined to the more inland and higher counties, such as Marshall and Lafayette. Further west such a deposit, if it ever existed, has been removed, and here, too, the Lafayette if it were ever thick has been almost entirely removed, leaving only a few feet of gravel and sand between the Loess and the Lignitic beds, as is the case at Askew's Bluff, Panola county. In the bluff at Vicksburg, too, in some places, only a few feet of such gravel intervene between the Loess and the Vicksburg limestone of the Tertiary.

Relation of the gravel deposits of north Mississippi to the Loess-Loam.—These gravels, in the main, are considered as primarily belonging to the Lafayette, but in many places they seem to have been worked over and redeposited in the Loess-Loam, or at its base, near their original location. The difference in the stratigraphic position of the pebbles of the eastern and western belts has already been noticed. In the former region, most, if not all, the pebbles have been worked over. These also contain a much higher percentage of chert pebbles—sometimes quite large and angular, or subangular—derived from adjacent Sub-Carbonifereous chert deposits.

The gravels of the western belt are found most frequently at the base of the Loam or Loess. Generally it is not practicable to determine whether they belong to the Loam (or Loess), or whether to the top of the Lafayette. But occasionally a few feet of Lafayette sand intervenes between the gravel bed and the surface formation. At the Memphis bluff, as we have seen, the gravels belong undoubtedly to the Lafayette. At a point eleven miles from Batesville, on the Batesville and Water Valley road, the following relations were observed: A hill mantled

with several feet of loam, which becomes thicker down the hillside and in the adjacent valley; near the hilltop the underlying Lafayette sands contain scattered quartz pebbles, while further down the hill, at a considerably lower level there is a well-defined pebble stratum at the base of the loam. Toward the hilltop the pebbles are evidently well within the Lafayette, while toward the bottom of the hill the pebble stratum seems to form the basal member of the Loam, though it is undoubtedly derived from the higher level gravel of the Lafayette (compare the relations of the Loess to certain gravels in southern Illinois *Am. Jour. Sci.*, Vol. XLI, p. 366 *et seq.*).

Similar gravels have been described by Professor Salisbury (JOUR. GEOL., Vol. III, pp. 655–667), from Devil's Lake, Wisconsin, where they underlie the Drift. They are therefore of Pre-Glacial age. Direct correlation of this deposit with the southern gravels is at present impossible, but it seems probable that both were laid down by the same "definitely limited set of agencies" acting within "a definitely limited period of time" — a period closed by the inauguration of the Glacial period in the North.

As to the conditions under which the Lafayette was deposited, I do not feel prepared to speak. However, it seems to me that Hilgard's view as stated in "The Age and Origin of the Lafayette Formation" (*Am. Jour. Sci.*, No. 257, Vol. XLIII), on the whole, is to be preferred; only we must look to another source than melting continental glaciers, for the floods which brought down and deposited the materials of the Lafayette.

B. *Upper limit of the Loess-Loam.*— This formation covers by far the greater part of the surface in this region, and it is only in the "second bottoms" and in the bottoms proper that we find materials of a possibly later age. Many of these "second bottoms" are simply low, broad terraces of degradation carved out of the Yellow Loam, as already noticed. Others are probably stream terraces of constructive origin. But as such deposits are confined to the vicinity of streams, deposition along streams proceeding *pari passu* with erosion of the general surface of the country; and because the materials of such terraces

have been derived wholly or largely from the Loess-Loam, and both formations being usually unstratified, we have no certain means of discriminating the two. And, indeed, the necessity for such discrimination seems very slight when we remember that the formation of these stream terraces began immediately after, or coincidently with, the general uprising which brought the Loess-Loam period to a close; and that they are local lowland deposits formed during a period of general elevation and erosion, rather than general deposits formed during a period of depression. The important point to remember is that the whole of the area under discussion has never been under water since the period of depression during which the Loess-Loam was deposited, and that the interval of general erosion, and "loss of record," which has existed here since the deposition of the Loess-Loam is represented by the contemporaneous deposits of lakes, streams, and adjacent shore lines. Geological history written on tablets of ocean bottom is comparatively easy to read, but written by lakes and rivers upon a scratched and mutilated continental surface, it forms a palimpsest very difficult to decipher by the aid of stratigraphy alone. As an evidence of the truth of this statement I desire to call attention to the different views prevailing among geologists as to the age of the low level deposits known as the Port Hudson group. Some consider this as the oldest of southern Pleistocene formations, others believe that it corresponds to the last epoch of glaciation. With this formation, however, the present paper does not deal, since these deposits are not to be found within the area under discussion. Loess has not been found, I believe, in the North corresponding to the Drift of the third Glacial epoch, yet it does not follow that the Mississippi did not continue to bring down drift material during this time which may have been added to previous deposits of loess or loam.

Nor can we say that this process may not have continued for some time after the final retreat of the ice beyond the Canadian line. If we consider that the Glacial period began in the United States when the land ice from Canada first crossed the

Archæan highlands between Canada and the United States, eroding in some places and in others depositing till; and if the final retreat of the same ice mass beyond the same highlands be considered as marking the close of the Glacial period, how shall we fix the limits of a formation in the south derived largely from glacial débris? Such deposits, no doubt, are still forming to some extent near the edge of the drift-covered area; and the deposit of till in the North must have begun in advance of the deposition of the Loess-Loam, and of the Natchez formation.

We may only say that the Loess-Loam in this region is homotaxial with the drift, that being composed largely of drift materials it cannot antedate the latter and that the two were in a general sense synchronous.

C. *Conditions under which the formation was deposited.*— For a discussion of the conditions under which the Loess-Loam was deposited the reader is referred to *12th Ann. Rep. U. S. Geol. Surv.*, pp. 401–404.

This formation is to be considered as being essentially a flood-plain deposit of glacial débris (worked over to some extent perhaps by the wind), and formed during a period of subsidence, when the whole surface of the country in this region was practically at sea level. The submergence of the surface seems to have been so slight that fresh-water conditions prevailed over marine, and currents laden with glacial débris ran far southward into a tideless bay. Indications, however, of brackish, or of marine conditions, are to be found in the present "salt-licks" which occur quite frequently in the Yellow Loam of some localities, such as Tate and Panola counties.

In the absence of shore lines to mark this incursion of the sea, evidence of submergence is to be found in the areal and vertical distribution of the formation, which no other causes seem competent to explain. Still more direct evidence is afforded by the presence in some localities of huge foreign bowlders imbedded in, or at the base of, the Yellow Loam, and which, it seems, could only have reached their present positions by iceberg action, or through some supernatural agency. A

very interesting deposit of siliceous sandstone blocks is found at Rockyford, Union county, Mississippi, twenty-two miles east of Oxford. Along the hills on either side of Tallahatchie River, near the village, blocks of hard white or gray sandstone either rest directly upon the soil (the prevailing position), or are loosely imbedded in sand. Some of these bowlders will weigh, perhaps, 300 or 400 tons, and many of them present square cut surfaces as if just plucked from some parent ledge. These extend for about one-half mile only on each side of the river. The nearest bed rock at all like these blocks is a Sub-Carboniferous sandstone found in southern Tishomingo county some fifty or sixty miles distant and across the Tallahatchie-Tombigbee divide, on the headwaters of the latter. These bowlders must have been brought down by icebergs from the north, or possibly from the northeast, coming down the Tennessee River valley and across the divide between this and the Tallahatchie, into the latter, where they deposited their load by melting or by overturning.

A smaller block of angular fossiliferous chert, weighing 150 or 200 pounds, was found at the juncture of the Lafayette and the Yellow Loam at a point about seven miles east of Senatobia, in Tate county.

Similar bowlders are reported from other parts of the State, but with these I am not personally familiar.

Absence of stratification in the Yellow Loam may be due in part to its deposition from sluggish currents overloaded with fine detritus (see "Conditions of Sedimentary Deposition," JOUR. GEOL., Vol. I), but the subsequent alteration of the deposit seems generally to have been great enough to have destroyed all traces of stratification which may have existed.

D. *Subsequent alteration.*—In the study of this formation it seems to me that the idea of great chemical alteration subsequent to deposition has not been properly stressed. The fact is evidenced by the present decayed appearance of the loam proper, and by the surface alteration of the loess; by the segregation of part of the lime and iron in the former into "buckshot"

and in the latter into calcareous and ferruginous nodules. At the contact plane of the former with older formations — the Lafayette around Oxford, or the Northern Lignitic a few miles east — there are frequently selvedges of "hardpan," or ferruginous sandstone, sometimes of considerable size, and occasionally containing a high percentage of iron. These are not to be confounded with similar "iron ores" of the Lafayette. That the loess has suffered less alteration than the loam is evident. The present difference between the two may be due partly to original difference in chemical composition and physical texture, but more largely I think to a difference in degree in subsequent alteration. The latter may be attributed to the difference in thickness of the two, which would both give to the loam a higher percentage of organic matter (derived from older soils), which on decomposition would furnish abundant solvent for its soluble constituents, and also allow a freer circulation of water for the accomplishment of the decomposition of putrescible matter and consequent leaching of the loam.

The roots of existing plants, too, may penetrate through the loam as they could not always the loess. But the Memphis sections would seem to indicate, also, original local differences in chemical composition and physical texture.

T. O. MABRY.

UNIVERSITY OF MISSISSIPPI.